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SYSTEMATIC ANALYSIS OF REFERENCE MODELS IN PRODUCT DEVELOPMENT: CASE STUDIES IN THE AGRICULTURAL MACHINERY AND IMPLEMENTATION SECTOR

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ABSTRACT

With the growth in the machinery and agricultural implements sector the importance of the area of Product Development Process (PDP) has expanded significantly in the last decades. The surge is due to increased competition among manufacturers, thus requiring high quality products with greater efficiency in their production processes. In addition, the management of the phases that comprise the PDP is considered complex by specialized literature and manufacturing companies. Thus, the objective of the study is to present the main reference models that contextualize the PDP in order to systematically analyze its methodological classifications.

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In addition, the research seeks to explore the work methodologies currently applied in the PDP of the agricultural machinery and implements manufacturers located in the northwestern region of Rio Grande do Sul - Brazil. The research adopted the Systematic Literature Review (SLR) and the case study as investigation methods, classified as descriptive and comparative, of an exploratory nature. As a result, it was possible to identify a set of reference models that are usually adopted to operationalize the PDP. Research has shown that project support tools are not used by companies, while design and industrial management tools are applied. Finally, it was verified that companies have little knowledge about reference models.

Keywords: Product Development. Reference Models. Agricultural Machinery and Implements.

1. INTRODUCTION

The current scenario of fierce competition in most industrial sectors requires organizations to establish mechanisms so that innovation in products and processes is a constant exercise and does not present errors. It is therefore important to organize and formalize Product Development Processes (PDP) in companies with the purpose of avoiding problems that are related to failures, rework and dissatisfaction of the comparator market (BERTOLDI et al., 2014; SCHOENHERR; WAGNER, 2016).

Their decisions are crucial and, if well thought out, become competitive strategies used to increase market share (ROSS; SHARAPOV, 2015). From the PDP, it is possible to identify the customers' desires, turning them into project criteria that will be developed to design technical and commercial solutions that together lead to the great acceptance of the products in the market (SAMAAN et al., 2012; MACHADO et al., 2006; SILVERIRA; MACHADO; RUPPENTHAL, 2017).

Due to the positive factors resulting from a well-structured PDP, product development methods are increasingly incorporated, as well as influencing product and process quality, has a strong influence on other aspects of competitive advantages such as innovation, cost, speed and reliability of delivery and its flexibility (LIZARELLI; TOLEDO, 2016). However, this is only possible through the effectiveness of PDP management that allows organizations to identify new trends and perceive changes in consumer habits (COSTA; TOLEDO, 2013, SMITH;

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TRACEY, 2016). In this way, it is possible and useful to construct models for the PDP (SMITH; MORROW, 1999; ENGWALL; KLING; WERR, 2005; ROZENFELD et al., 2006; ROMANO, 2013).

The model is required for the standard product development process to be reused by multiple people. In addition, the model is used to demonstrate the reality of the company's production process, helping people to represent and understand all internal interactions that are not always evident. As development projects are defined from the model, it is known as the reference model (ROZENFELD et al., 2006).

In the last decades, several successful cases of companies and countries in terms of product development have demonstrated that the performance of the PDP depends on the model and management practices adopted (ROZENFELD et al., 2006; COSTA; TOLEDO, 2013; SCHOENHERR; WAGNER, 2016).

Although it is a process with a high degree of uncertainty and low predictability of results, it is possible and necessary to manage the PDP, planning, executing, controlling and improving activities, in search of better performance and learning results that together competitiveness (JUGEND, 2006).

However, mechanisms that include improvements in the PDP and application of reference models are complex for the literature of the area and for the companies (ROZENFELD et al., 2006; BARBALHO; ROZENFELD, 2013; BERGAMO; ROMANO, 2016; ECHEVESTE; ROZENFELD; FETTERMANN, 2017).

The complexity is related to the dynamic nature, the great interaction with the other activities of the company, the large volume and, especially, the diversity of information of an economic and technological nature that is manipulated during the process (CLAUSING, 1994; PRASAD, 1996; TATIKONDA; ROSENTHAL, 2000; FRISHAMMAR et al., 2011).

In this context, the present work has two main objectives. In the first place, we seek to classify, through literature, the structures of reference models for the PDP. Subsequently, we identify which are the most important attributes in the PDP to know if there is predominance of one group in relation to the other. Finally, the aim is to evaluate the use of formalized product development processes in companies in

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the machinery and agricultural implements sector in the northwest of the Brazilian state of Rio Grande do Sul (RS).

It is worth noting that despite the proposition of the methods found in the literature on the PDP, it is not the purpose of the research to define with rigor the semantics and the syntax of the methods. The objective of the systematic analysis of the methodological classifications of the reference models is to demonstrate which perspectives or methodologies should be adopted for a better performance of the PDP and also to facilitate the application of the same.

Thus, initially the work presents a theoretical rescue on the sector of Agricultural Machinery and its main aspects. Subsequently, the importance of the development of products for the agricultural machinery sector is contextualized. In the sequence, it is presented the methodological approach that was used in the study and the results found. Finally, the conclusions of the surveys and their respective references are presented.

The main contribution of the article to the literature is the identification of qualitative and exploratory product development variables for the structuring and adaptation of the reference models of the companies analyzed. The propositions and reflections raised in the study also contribute as subsidies for future academic research on the subject, which may give continuity to this initial study.

2. LITERATURE REVIEW

2.1. Agricultural Machinery Industry

In Brazil, an agricultural machinery industry is important in the economic and social aspect for the country, which has subsidiaries of the world's largest manufacturers, known as anchor companies that produce products, harvesters and agricultural implements. The sector presents a heterogeneous structure where companies of different sets and characteristics coexist (ROMANO, 2003; BERGAMO, 2014).

In view of this, as companies seek to specialize in a defined set of products, allowing their participation in various market segments. It is possible to circumvent as frequent oscillations in the demand for products, due to the quality that characterizes the agricultural activity, as well as in the manufacture of parts for other

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companies producing agricultural machines (OLIVEIRA; DALLMEYER; ROMANO, 2012; ROMANO, 2013).

The products of the companies of the agricultural machinery sector are generally divided into: tractors; machines for soil preparation; seeding and fertilizing machines; machines for cultural treatments; grain harvesting machines; and machines for grain processing (ROMANO, 2003).

In this context, it is important to note that the Brazilian federal government has made numerous lines of credit available to small, medium and large rural producers. These are programs such as PRONAF - More Food (National Program for Strengthening Family Farming), for the production of soybeans, wheat, rice and other agricultural products. Financial agents such as MODERFROTA also provide investments that foster the productive chain of agricultural machinery in the country (FARIAS, 2014; MAPA, 2015).

With credit lines, small and medium-sized rural producers have leveraged the market for wheel tractors with potential of 73.97 HP (Horse Power). Through the incentives provided by the federal government, the machinery and agricultural implements market overcame the crisis that began in 2005 and continued until 2006 when the low dollar prices occurred (BERGAMO, 2014).

The estimation of the Brazilian production of agricultural machinery is performed by the number of self-propelled machines produced and sold, since there is no record of information on the production and sale of agricultural implements. However, due to the way in which mechanized equipment is used in agricultural properties, it can be stated that the performance of the latter follows the numbers of the first one (BERGAMO, 2014; FARIAS, 2014).

Currently, data on the production of equipment in Brazil shows that of the total number of machines produced in 2016, 27.2% of the volume came from companies based in the State of São Paulo (SP); 2.3% in the State of Minas Gerais (MG); 21.7% in Paraná (PR); and 47.8% in the State of Rio Grande do Sul (RS). It is important to mention that the performance of the Brazilian agricultural machinery industry went through an excellent period of production growth from 2010 to 2013, but in the following years it suffered sales drops (ANFAVEA, 2017).

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The oscillation in the production of agricultural machinery and implements is the result of different factors present in the agribusiness production chain, such as: climatic conditions, which directly interfere with the production of grains; the value of commodities, production, exports and government incentives; the degree of equipment obsolescence (due to its long life cycle ranging from 10 to 15 years); among others (ROMANO, 2003; BERGAMO, 2014). Figure 1 shows the Brazilian production of agricultural machinery and wheel tractors, responsible for the largest participation in the agricultural machinery market, from 2006 to 2016.

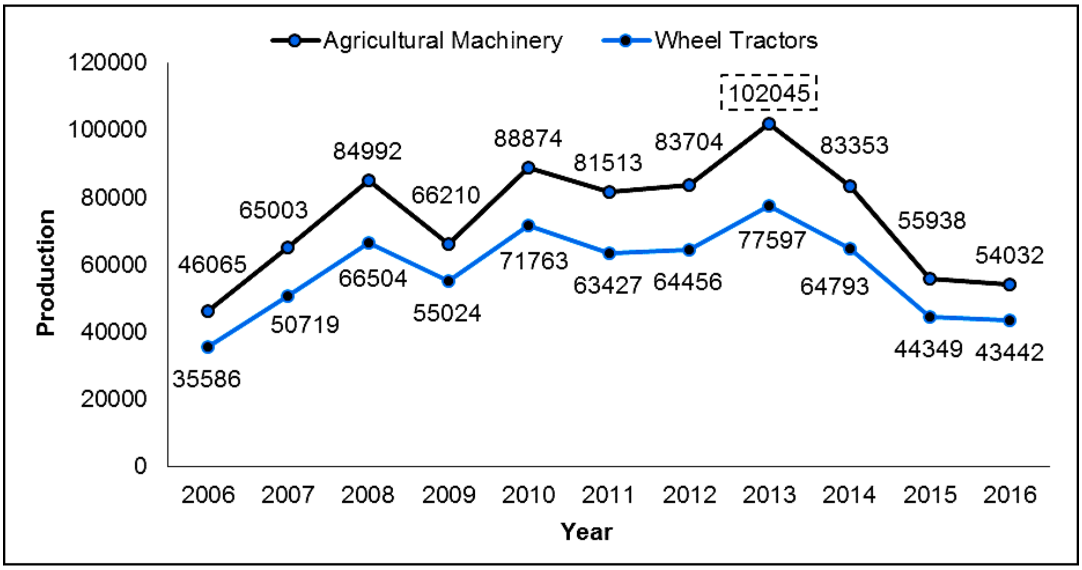

Figure 1: Sales of agricultural machinery and wheeled tractors - 2006/2016.
Source: Prepared based on data from ANFAVEA (2017).

It can be seen in Figure 1 that the agricultural machinery sector in Brazil suffered a significant drop of approximately 32.9% in production in 2015 compared to the previous year. In 2016, production increased again, from 55.938 thousand units produced, the production index was the lowest since 2007.

For the state of Rio Grande do Sul, the machinery and agricultural implements sector is relevant from an economic and social point of view (CARVALHO; CARRARO; SHIKIDA, 2016). In RS, there are several agricultural implements factories, which make the state with the largest number of companies in the sector and the largest exporter of agricultural equipment in the country (ANFAVEA, 2017).

From this, using the RS numbers as reference, some characteristics of the companies that make agricultural machines are presented. According to Passos and Calandro (1999), in terms of company size, 82% of the installed companies are small (less than 99 employees), 11% are medium-sized (from 100 to 499 employees) and

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7% are large (more than 500 employees). As far as the origin of the companies, they are predominantly national, not belonging to large economic groups, being most of family origin. It should be noted that there is an exception in the case of tractor and harvester manufacturers, where the companies are multinational (ROMANO, 2003).

As reported by the Ministry of Development, Industry and Foreign Trade, and the National Investment Information Network, 60% of the total Brazilian machinery and agricultural machinery manufacturers are based in Brazil (BRASIL, 2012). Among the manufacturers located in the State, three companies account for the greater productive power of agricultural machinery, concentrating, in the RS, one third of the labor force of this industrial sector of the country (ANFAVEA, 2017).

In RS there are about 641 companies located predominantly in the Northwest of the State (77.78%). The industries of the sector are present in at least 35 municipalities gauchos and concentrate 93% of the effective jobs. Among the Gaucho cities linked to the sector, it can be noted that ten of them have the concentration of 79% of the establishments connected to the machinery and agricultural implements sector and 505 establishments (BRASIL, 2012).

Among the large companies in the state of Rio Grande do Sul, there are six units of three of the world's leading players in agricultural machinery, formed through foreign capital. In addition, there are large and medium-sized companies manufacturers of implements destined to the internal and external market and by small companies, of national capital, that produce equipment of little complexity, and that are focused on serving customers and regional demands (SILVEIRA; MACHADO; RUPPENTHAL, 2017).

The companies based in RS develop as main activities: measuring instruments and instruments, machines, tools, general purpose tools and agricultural implements for use in agriculture; post-harvest machinery and equipment, sorting and storage; machinery and equipment for all types of irrigation; parts, accessories and components; wheel tractors; harvesters; among others (ROMANO, 2003). In this way, it can be said that the companies of the machinery and agricultural implements sector in RS are fundamental to the state economy and, consequently, generate direct reflexes in the entire production chain (BRASIL, 2012; BERGAMO, 2014).

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Although the segment presents advances, there is a need for constant updating and development of methodologies for the design of products that can help companies, identify customer needs and transform requirements into precise changes of their products (ECHEVESTE; ROZENFELD; FETTERMANN, 2017). Thus, it is important that product development processes that are appropriate to the reality of small businesses, which usually develop new technologies for small rural producers (BERGAMO; ROMANO, 2016).

The role of small companies is to implement, apply, differentiate existing products and adapt innovations within the technological trajectories (ROMANO, 2003). These trajectories represent a set of technological innovations that are developed after the launch of a radically new technology in the market, and it is up to small companies to diffuse and adapt the new technologies - complementing the role of large companies (MENDES, 2008; UNGER; EPPINGER, 2011).

2.2. Product Development for the Agricultural Machinery Sector

In the context of the agricultural machinery industry, there is a need to carry out PDP studies. The informality of the process of development of agricultural machines practiced in a large number of companies in this industrial segment (BERGAMO; ROMANO, 2016) is well known.

Agricultural machinery companies in general do not adopt and do not use systematic procedures to carry out the PDP, and it is easy to find examples where the PDP is carried out only according to the experience of those responsible. Moreover, even in the companies that carry out the process with a certain degree of formality, deficiencies can be observed, especially in the phases involving the product design.

The lack of application of knowledge such as simultaneous engineering and design methodologies bring many challenges, which start in the process of translating market needs or desires into product design requirements, ranging from concept-generation issues to machine failures in operations (ROZENFELD et al., 2006; ROMANO, 2013).

The PDP includes a macroprocess, known as Innovation Management (GI), which contains a set of factors such as the generation and evaluation of ideas, the

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process of developing technologies and market trends that are fundamental for long-term survival and competitiveness companies (LIZARELLI; TOLEDO, 2016).

With the presence of the different factors of innovation management, it is possible to see that the PDP uses the procedures and methods that the companies have to design new products and make them available in the market (UNGER; EPPINGER, 2011). In the process of developing agricultural machinery, the definition of market demand and the adaptation of existing machine designs determine the advancement of technologies, resulting in products launched on the market with characteristics similar to those of competitors and with a low prospect of technological innovation (BERGAMO, 2014).

However, the process of innovation management is a complex task in organizations and to be carried out correctly, it is necessary to verify the competitive and strategic context that is intended to encompass and, mainly, to develop organizational parameters that support it (SILVA et al., 2014).

Within this context, there is a lack of information on the process of development of agricultural machinery, especially as regards the detailing of its specificities, which, together, serve as the basis for the specification of product development projects. For the authors Oliveira, Dallmeyer and Romano (2012), there is also a need to use methodologies with an emphasis on strategic product planning and agricultural machinery design. In addition, the authors state that one must also consider marketing mechanisms to achieve product success.

Thus, a reference model for the agricultural machinery development process can serve as a guideline for companies to implement a formal product development process, or to incorporate improvements to the already established process (ROMANO, 2013).

The reference model seeks to make explicit the knowledge of the PDP in order to assist in the understanding, the practice of the process and the execution of a more formal and integrated PDP to the other business processes with the participation of suppliers and customer. They are general characteristics of a reference model: i) decomposition into macrophases, phases, activities and tasks, with logical sequence of them; ii) presents, through graphic representation, the entire development process; iii) the process is in line with the company's strategic plans; iv)

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defines the areas involved in each stage of the process; v) explains what, when and how to do, based on the principles of engineering; vi) defines the areas involved in each step of the process (BACK et al., 2008).

According to Romano (2013), the process of development of agricultural machinery is represented in the reference model by three macrophases: i) project planning; ii) elaboration of the project (design) of the product and iii) implementation of the pilot batch. Each of the macrophases has a connection with the phases of the process, their respective outputs and the knowledge domains linked to the process activities. It is understood that the adoption of a reference model for the product development process has the purpose of making the process more efficient and effective (CLARK; FUJIMOTO, 1991; WHEELWRIGHT; CLARCK, 1992; COSTA; TOLEDO, 2013; ROMANO, 2013).

This, in turn, can bring greater competitiveness of the company in the market, enabling the launch of products with higher level of improvement to the others and with greater technological innovation, formalizing the process management model and improving the involvement of the several areas in the development of product (ROZENFELD et al., 2006; OLIVEIRA; DALLMEYER; ROMANO, 2012; BERGAMO; ROMANO, 2016; LIZARELLI; TOLEDO, 2016; ECHEVESTE; ROZENFELD; FETTERMANN, 2017).

3. METHODOLOGY

3.1. Systematic Literature Review

In order to carry out the initial stage of the research, it was necessary to develop the formulation of the research problem and its delimitation, focused on the interface between the project area and agricultural machinery. Next, the general and specific objectives of this work were elaborated. In the third stage, the theoretical study was made. To carry out the theoretical part of the research, the method of Systematic Literature Review (SLR) was selected. The SLR methodology uses as a data source the existing literature on a given theme, selects and evaluates contributions, analyzes and synthesizes data (BIOLCHINI et al., 2005; CONFORTO; AMARAL; SILVA, 2011).

In addition, it describes the evidence in order to allow clear conclusions about the topics that are already known, as well as what is not known about the subject

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matter (DENYER; TRANFIELD, 2009). The analysis of the research is characterized as theoretical-conceptual and objective to present the main reference models that contextualize the PDP with the purpose of analyzing its methodological classifications (LOPES; CARVALHO, 2012).

The scope of the literature review includes articles published in journals and journals that deal with the reference models developed for the PDP. The Science Direct, Emerald, SciELO and Web of Science databases were selected because of their breadth and relevance to the areas of knowledge covered by this research (business, management, economics, engineering and related areas).

To perform the advanced searches in the databases, it was necessary to make use of logical operators. Subsequently, it was necessary to establish the keywords (without quotes and without refinement by area of knowledge) to be used in the theoretical survey in the databases. After the searches, the refinement of the research considered all the years available in the databases, selected only works written in English or Portuguese and documents of the type "article", "review" or books and book chapters.

The terms used in the research were: reference models and product development process. For the files available in full, it was necessary to perform a complete reading and their references were observed (snowballing) to ensure that other relevant works were not detected in the original research. After applying the filtering based on the explicit criteria previously, approximately 225 articles were identified.

We excluded 103 articles that were not related to reference models and because they considered only some phases of the PDP. Subsequently, the abstracts that considered the established terms were evaluated and 35 other works were excluded, which emphasized the initial stages.

Finally, another filtering was carried out with emphasis on the introduction and conclusion, being excluded another 32 works respectively. Thus, 55 papers were used as research material, 14 of which were selected because they contain more details about the execution of the PDP phases. The SLR methodological flow of the research is shown in Figure 2.

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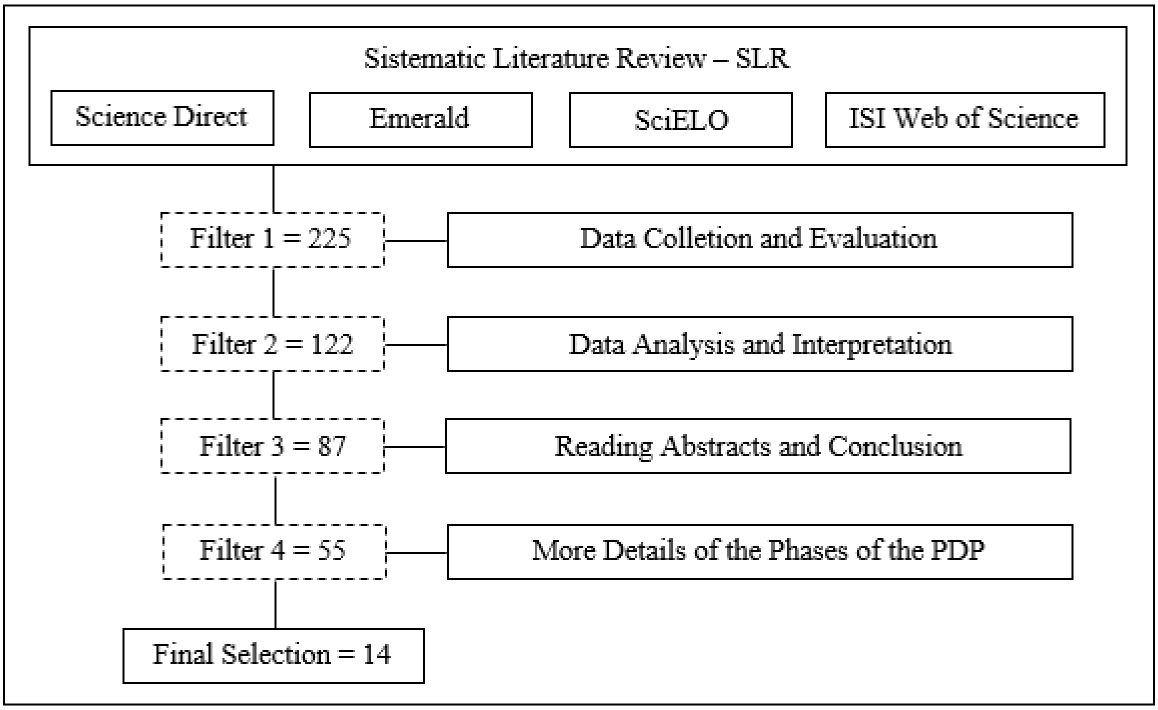

Figure 2: Presentation of the methodological flow of SLR.
Source: Authors (2017).

The research sought to select different approaches of the classifications of the PDP phases, in order to demonstrate the evolution and progress of the structure of the reference models that are used concomitantly in academic research and companies. It is important to emphasize that the efficient management of the PDP is one of the factors of success of new products, besides being responsible for the reduction of development costs. One of the major difficulties currently encountered in PDP management is the existence of partial views and through the reference models it is possible to foster a holistic view in the PDP to improve its performance.

3.2. Case Studies

To carry out the case studies, the development and continuous launch of new products was established as a criterion for the selection of companies in the machinery and agricultural implements sector. Through the case study it is possible to verify which are the instruments and procedures used by the companies and also to provide an exploratory view, in which the relevant variables are not yet fully determined and the phenomenon is not completely known. According to Yin (2001), the case study is among the most appropriate methods to conduct qualitative and exploratory research in engineering. Case study is also preferable in the analysis of contemporary events when relevant behaviors cannot be manipulated (MIGUEL,

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2007). According to Yin (2001), the phenomenon can be studied in its natural and significant environment. Figure 3 systematically demonstrates the steps taken in the research case studies.

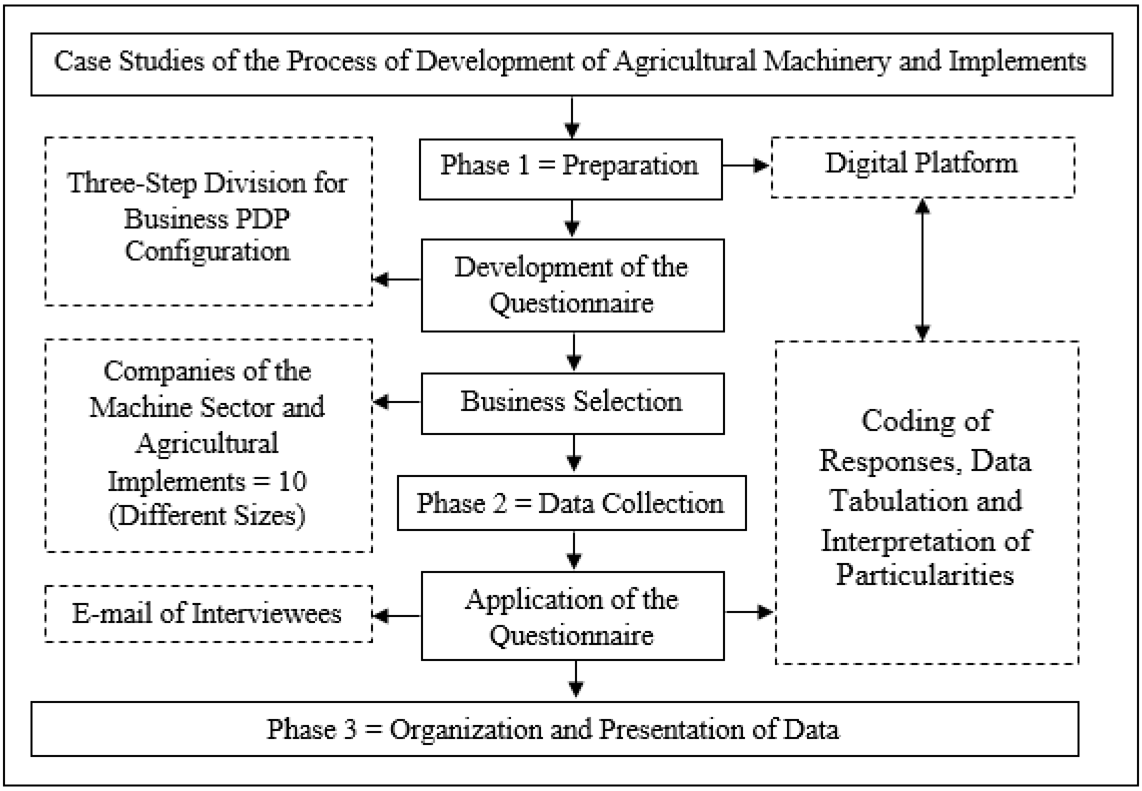

Figure 3: Steps taken in the case studies.
Source: Authors (2017).

The data collection was performed based on a questionnaire applied to 10 companies in the agricultural machinery and implements sector and the results obtained in the research underwent a process of analysis. The questionnaire used was divided into three parts: i) collection of information referring to the general data of the companies; ii) characterization of the product development sector; and iii) PDP characterization.

Its structure was based on the same principles of research carried out by Romano (2003) and Silveira, Machado and Ruppenthal (2017). The first part of the questionnaire aimed to characterize the company, in relation to the number of employees, product line and their respective certifications (ISO 9001). Regarding the characterization of the product development sector, the questionnaire seeks to identify the design of the identification, organization of the sector and the distribution of the project activities.

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Subsequently, the information pertinent to the PDP was identified, specifically with regard to the types of projects carried out by the company, the complexity of the projects and their manufacturing process, the involvement of suppliers, planning, formality and way of conducting the process, process representation, standardization and documentation of the projects and the tools used during the respective activities.

A case-study was defined as a case-study of multiple cases in small, medium and large companies, with the purpose of studying the process employed by the companies that are part of the northwest region of Rio Grande do Sul. It is highlighted that companies they agreed to participate in the research and did not emphasize a specific class of companies (size) because the general structuring of the research is classified as descriptive and comparative, exploratory in character (CONFORTO; AMARAL; SILVA, 2011).

The data collection was performed based on a questionnaire applied and the results obtained were analyzed considering the objectives proposed in the research. Thus, it is possible to detect problems that may occur in the acquisition of information for the research. According to Miguel (2007), the results of the case studies should be closely related to the research topic, thus generating concrete results and conclusions. In order to maintain the confidentiality of the companies, numbering was used to characterize them.

In order to analyze the information, the answers were coded and the data were tabulated with the purpose of interpreting the particulars of each case. The questionnaire was applied through the use of a digital platform (Google Drive), facilitating the storage of files and the formulation of questionnaires using the Internet as a means to apply them in companies.

Thus, only the electronic address (email) of the person responsible for the PDP sector in the company selected in the study is required to submit the questionnaire. The procedures used to analyze the information were: coding of the answers, tabulation of data and interpretation of the particularities. The data resulting from the case studies, according to Figure 3, were used as a basis to characterize the process of development of machines and agricultural implements destined to the companies participating in the research.

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4. RESULTS AND DISCUSSION

4.1. Product Development Methods

Existing models for product development involve principles and concepts that represent different views of the operation of the PDP. Thus, different authors differ on the number and definition of the stages that involve the PDP. For Kasper (2000), the structure of the Reference Model for the PDP of the companies must contemplate the standards, knowledge and principles that assimilated together result in the mental model from which are developed methodological procedures and several languages to describe the phenomena, situations and contextual problems.

Another analysis can be verified through the methods and the utilities that each author has proposed, over time, that can be recognized by their research techniques and the initiative to generate not only a set of procedures, but several alternatives that, in synthesis, converge in the same direction: that of being able to solve a problem that meets or goes beyond the user's needs (KINDLEN JÚNIOR; CÂNDIDO; PLATCHECK, 2003). Table 1 shows the reference models that were selected in the SLR, each one with its peculiarities and methodological classifications of the PDP.

Table 1: Reference models and classification of the PDP methodological steps.

Model/Author	Perspective	Methodological Classifications
Asimow (1962)	Engineering Design	I - Identify primary need; II - Study the feasibility; III - Design preliminarily; IV - Design in detail; V - Plan production; VI - Plan the distribution; VII - Plan consumption; VIII - Plan the withdrawal of the product.
Back (1983)	General	I - Study feasibility; II - Design preliminarily; III - Design in detail; IV - Review and test; V - Plan production; VI - Plan the market; VII - Planning for consumption and maintenance; VIII - Plan for obsolescence.
Clark and Fujimoto (1991)	Automotive	I - Product design; II - Product planning; III - Product design; IV - Project of the process.
Wheelwright and Clarck (1992)	General	I - Divergence: Obtain primary information; Explore the project situation; II - Transformation: Perceiving or transforming the structure of the problem; III - Convergence: Find parameters; Describe sub-solutions; Identify contradictions; Combining sub-solutions into alternatives; Evaluate alternatives; Choose solution (final design).

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Pahl et al. (2005)	General	I - Plan the task: Analyze the market, company and conjuncture; Find and select ideas; Clarify the task; Elaborate list of requirements; II - Develop the principle of solution; III - To develop the structure of construction: To form preliminary body; Select preliminary studies; Refine the preliminary form; To evaluate; IV - Design the definitive form: Eliminate weaknesses and errors; Prepare preliminary list; Prepare instructions for production and assembly; V - Develop documentation for manufacturing: Detail, complement and verify the documentation.
Matsou (2006)	Textile	I - Definition of the product; II - Conceptual project; III - Functional design; IV - Basic interlacing project; V - Basic design of manufacture; VI - Detailed design of manufacture.
Rozenfeld et al. (2006)	General	(1 - Pre-Development): I - Strategically plan the products; II - Plan the project; (2 - Development): I - Carry out the Informational Project; II - Carry out the conceptual project; III - Carry out the detailed project; IV - Prepare the production; Get manufacturing features; Plan pilot production; Receive and install features; Produce pilot lot; Homologate the process; Optimize production; Certify the product; Develop manufacturing and maintenance processes; V - Launch the product: Plan launch; Develop sales, distribution, service and assistance processes; Promote marketing; Launch product; Manage launch; (3 - Post Development): I - Follow the product and process: Evaluate customer satisfaction; Monitor performance; Conduct post-project audit; Record lessons learned; II - Discontinue the product: Analyze, approve and plan the discontinuity; Prepare and monitor the receipt of the product; Discontinue production; Finalize product support; Evaluate and close the project.
Colenci Neto (2008)	Software	Strategic planning; planning; elaboration; construction; Test; homologation; implantation; maintenance and support; project control; discontinuation of the product.
Campos and Ribeiro (2011)	Wheat Mill	I - Pre-development has the phases: product portfolio planning and project planning. II - Development has the phases: informational project, conceptual project, detailed design and production preparation and product launch. III - Post-development has the following phases: product and process monitoring and withdrawal of the product from the market.
Barbalho and Rozenfeld (2013)	Mechatronics	I - Project planning; II - Conception; III - Technical Planning; IV - Technical Project; V - Optimization; VI - Homologation; VII - Validation; VIII - Release; IX - Monitoring.
Bottani et al. (2013)	Mechanical	- Identification and generation of ideas; II - Idea selection; III - Development of the product concept; IV - Product concept test; V - Development of market strategy; VI - Manufacture of the product; VII - Testing of the product on the market; VIII - Launch of the product.

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Romano (2013)	Agricultural Machinery	I - Planning macrophase: which covers the planning phase of the project itself; II - Macrophase of projection: that involves the phases of elaboration of the informational, conceptual, preliminary and detailed projects of the product and of the manufacturing process; and III - Implementation macrophase: which includes the phases of preparation of the production, launch of the product in the market, validation of the agricultural machine and closure of the project.
Costa and Toledo (2013)	Ceramic	I - Pre-development: management of strategic product planning and project planning; II - Development: informational project, conceptual project, detailed design, production preparation and product launch; and III - Post-development: follow product and process, discontinue product.
Moretti and Braghini Junior (2017)	Clothing	Macro phases: (I) pre-development, (II) development and (III) post-development. Micro phases: (i) collection planning, (ii) portfolio product planning, (iii) market research, (iv) concept definition, (v) details, (vi) pre-production, (vii) product launch and (viii) monitor the product/process.

Source: Authors (2017).

As stated by Roozenburg and Eekels (1995), until the 1990s the PDP emphasized only three stages. The first dealt with the project phase, which was aimed at solving the problems and structuring a logical reasoning called the basic project cycle (analysis, synthesis, simulation, evaluation and decision) that helped to make the project effective.

The second focused on segmenting the engineering project, dividing it into four phases (project specification, conceptual design, final design and detailed design). The third was responsible for structuring the phases of the PDP, which were formed by the phases of the product design, part of the preparation and development of the production and the marketing plan transforming the PDP vision as part of the business.

In this context, when analyzing the methodological details of the reference models presented in Table 1, there is a lack of information on the performance of the product and measures aimed at reducing the environmental impacts of the products. In the stages in the models, there are no phases that use strategies of recycling, remanufacturing and disposal of products and packaging.

According to Rodrigues et al. (2017), a systematic and simplified integration of green practices into the PDP is necessary to improve the sustainable performance of enterprises. In addition, regarding the project planning phase, an important topic for

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the authors under analysis, the context of sustainability is not referred to with emphasis on PDP structures.

The most recent PDP structures (from the years 2000 to 2017) seek to improve the management and integration of the PDP and, by visualizing Table 1, it can be seen that all phases of the PDP complement the PDP structures developed in previous periods.

According to Campos and Ribeiro (2011), the PDP can include other structural typologies, such as: improving management practices, considering the entire product life cycle, integrating support tools, aligning the organization's strategy with the PDP, integrating all the supplier chain and customers, analyze the implications of knowledge management, improve information flow, use modularity concept, define responsibilities and support decision making.

Through the systematic analysis of the methodological classifications of the reference models of the different authors it is possible to identify also that the purpose for the PDP is focused on the division into macrophases, phases and activities. In general, it can be said that the macrophases are sequential, the consecutive phases can have parallel activities and the activities within each phase are simultaneous.

In addition, it is verified that the PDP's initial vision with emphasis on linear activities, characteristics of development macrophases, adopts the PDP vision as a business process, that is, align the PDP with the company's strategic planning, integrating all the its internal and external areas. With respect to the particularities, perceptions of improvements in the PDP in recent years are being developed for specific market segments (COLENCI NETO, 2008; CAMPOS; RIBEIRO, 2011; BARBALHO; ROZENFELD, 2013; ROMANO, 2013; COSTA; TOLEDO, 2013; MORETTI; BRAGHINI JUNIOR, 2017). However, they use as basis for development the generalist model of Rozenfeld et al. (2006).

In all models resulting from SLR there are no relationships of the PDP phases with emerging themes (Industry 4.0, Internet of Things, Artificial Intelligence, among others). For Santos et al. (2017), opportunities such as reduced product costs, quality products, and data exchange can be identified in the PDP phases by comparing them with the concepts of emerging themes, especially Industry 4.0.

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According to Rauch et al. (2016), in order to develop new products that are successful in the market, the PDP should undertake a substantial transformation. According to the same author, the new phases of the PDP will be derived from the use of advanced and modern technologies and instruments necessary to optimize the intelligent factories. For Santos et al. (2017), one of the main features of the new PDP is the integration and virtualization support of the manufacturing and production process that is dependent on the use of information and the Internet to create intelligent products. Thus, the new product development methodologies will facilitate a high flexibility and cooperation among the active agents in the PDP in general.

4.2. Company Characterization

The information collected on the case studies allows us to express that each of the companies surveyed has its own characteristics, methodologies and ways of carrying out its activities, according to its size, organizational structure and also its knowledge about the various stages involved the PDP. In the agricultural machinery industry in general, the structuring and integration of activities and the industries themselves is precarious.

In its breadth it does not use structured product development research methods or multivariate statistical techniques to identify market segments, opportunities for new forms of segmentation and/or new types of clients. As the field of action is broad and with the new tendencies of modern agriculture, the PDP of the companies is complex, because factors like the organization and control of the activities are not flexible throughout the life cycle of the product. Table 2 shows the characteristics of the companies that participated in the survey.

Table 2: Characterization of the companies interviewed.

Company	Respondent's Role	Company Activity	Number of Employees	They have relations with Reference Model	Company Size
1	Quality Inspector	Manufacture of Agricultural Implements	2500	✓	Big
2	Production Coordinator	Machines and Equipment	500	✓	
3	Production Manager	Casting and Machining	900	✓	
4	Production Coordinator	Parts and Agricultural Implements	1500	✓	

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5	Management	Manufacture of Agricultural Components	250	✓	Medial
6	Production Supervisor	Machines and Equipment	180	-	
7	Production Manager	Agricultural Machinery	240	-	
8	Project Leader	Metallurgy	175	✓	
9	Quality Manager	Agricultural Machinery	75	-	Minor
10	Product Director	Machines and Equipment	90	-	

Source: Authors (2017).

The main products manufactured and marketed by the companies are: parts for tractors, harvesters, seeders, sprayers, carts, distributor of fertilizers, among others. With regard to the certification of companies by the norm NBR ISO 9001, which governs all phases of the production process, from product design to technical assistance, companies 6 and 10 stated that they do not have the certification and the PDP is carried out informally, from the identification of a new opportunity in the market or the need for internal improvements.

In addition, they do not feature an engineering industry that works in conjunction with product development. The relationship of the sectors is important to streamline the productive process and with continuous improvements in the quality and flow of information within the PDP. Correcting the lack of organization in the process and delays during the activities of both companies.

Regarding supplier participation in product development, in company 3 the supplier can assist in APQP (Advanced Product Quality Planning), that is, it may interfere with the procedures and techniques used to manage productive quality. Currently, APQP is employed in automotive companies in order to ensure the quality of the products and processes developed in its plant, and is governed by the APQP manual, translated in Brazil by IQA (Institute of Automotive Quality). The same company also said that the supplier can participate in the final stages of the Try-out (tool tests).

Regarding the adopted procedures that may or may not be represented by a schematic model containing the main phases, steps or tasks, companies 1, 2, 3, 4, 5, 6, 8, 9 and 10 stated that they have relationships with the models from Table 1.

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Only company 7 responded that standardized and documented procedures are not performed and adopted.

Another negative point is the lack of security and privacy - which involves such items as communication confidentiality, message integrity, authenticity, as well as access selection of objects to only a few services or restrictions of communication from one object to another at certain times throughout the product development process. Company 1 specified that a POS (Standard Operating Procedure) is performed, which describes all the operations necessary to carry out an activity, that is, it is a standardized route to carry out an activity.

Generally, most companies that use this type of form have a Procedures Manual that originates from the organization's flowchart. Complementing this task adopted by the company, the POS can be applied, for example, in a company whose employees work in three shifts, without the workers of these shifts meeting and, therefore, perform the same task differently.

Among the tools used in product development, product management and design, there were different answers among all companies participating in the questionnaire. Companies 9 and 10 reported that the tools used are: welding, bending, painting and assembly.

It is noted, then, that are procedures adopted to manufacture or produce the product, not tools to manage the project. Large companies reported that development meetings, APQPs as described above and EMS (simultaneous engineering with activity records for each person with a schedule and defined deadlines) were carried out. For the other case studies concerning the management and design of the product, it is noted that Computer Aided Design (CAD) software is used in the design and structural analysis.

Also considered are spreadsheet software, electronic text editors, and the respective Enterprise Resource Planning (ERP) management software of the Integrated Enterprise Management Systems (SIGE or SIG) used to manage of all management activities, such as financial management, accounting, human resources, manufacturing, sales, purchasing, among others. Companies 9 and 10 do not use tools to support the project, nor even CAD software, demonstrating that

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when drawings are required, they must hire outsourced companies to carry out these activities.

Through the case studies it was identified that the main difficulties of the PDP in the agricultural machinery sector are related to the lack of focus/priority to carry out research of trends and definitions of concepts to increase the process and also, with respect to the management of people, because they work with relatively small project teams.

In addition, in all companies there was no evidence of the adoption of sustainable principles in the schematic models or in the project methodologies adopted. Regarding the emerging themes, companies do not present phases, stages or tasks that contemplate characteristics that can configure an initial frame of the new approaches. However, it is worth stressing that even so, large companies stand out for having an agile and efficient development process, resulting from the experience they present in the agricultural machinery sector.

5. CONCLUSIONS

The article sought to review the existing literature on product development methodologies, in order to verify which are the main components of the reference models. In addition, it sought to identify barriers and facilitators that can help agricultural machinery companies redefine their business models to take advantage of opportunities to expand product development strategies.

We analyzed 225 articles, which are published in international journals, mainly in the area of management, product development and new methodologies. However, much of the literature reviewed brings theoretical essays or comments, but there are few empirical research on business models for products that discuss new approaches to research, especially Internet of Things (IoT).

Having a network of intelligent and connected devices means that it is possible to design agricultural machines with self-regulation systems, which represent the advance to more automated production, with smarter supply chains and better use of scarce resources.

With regard to the companies studied it can be said that there is no adequate definition to the target market and that it uses structured, planned and deliberate methods. They are defined through unsystematic, gradual and unpretentious

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decisions made during the evolution of the company and the relationship with the market.

They do not have a target market delimited, focused and adequately formalized; and in companies 9 and 10 the target market is not consciously defined, whereas the types of customers of interest to the organization are not established throughout the product development process, where services are provided to any possible customer types of where new customers are won only on the basis of available funds for communication or where the target customer profile established by the organization is not applied.

It has been found that small and medium-sized enterprises use little effort in implementing differentiation strategies and have employees, partners and intermediaries who are not adequately informed and aware of the competitive differentials of the organization. In addition, they do not determine differentiation strategies based on structured procedures, planned, deliberate and conscious decisions, but as a result of the organization's daily characteristics and/or decisions that have been evidenced in a gradual, casual and undesired way.

The companies 6, 7, 9 and 10 do not use and present relationships with structured systematics for the sequencing of activities and tasks, according to the models in Table 1, which should be used as formal research methods, statistical analysis methods or perceptual mapping. It should be emphasized that all the companies studied apply strategies of market segmentation, competitive differentiation and brand positioning or services, but lack more planned, structured, deliberate and formalized methods and techniques, as well as greater effort in the implementation process, in order to achieving improvements in PDP performance.

Based on the above mentioned considerations, some recommendations should be considered regarding systematics, techniques and ways of implementation if they are to achieve better results with the application of new organizational trends for the PDP.

The recommendations are as follows: (i) to conduct empirical research, exploratory testing, and to analyze actual cases of business modeling for services and products based on IoT devices; ii) structure empirical studies that point out the opportunities (facilitators) of generating business models for IoT- based products and

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services; iii) to develop exploratory research on the barriers in the introduction and prospection of digital innovation in its business processes and productive processes and how they can be overcome; iv) to elaborate statistical studies that verify information technology capacities need to be developed by the organizations for the appropriate establishment of business models and obtaining the expected benefits of IoT; v) to deepen studies that address the innovation in services and the servitization brought about by the intensive use of digital technologies, especially by IoT.

In this way, the work contributed to those who seek to better understand the definitions and concepts related to PDP and new technologies, thus providing researchers and stakeholders with a study on the subject. As a limitation of the research, it is possible to say that with respect to emerging themes and classical theories of product development, there is not a significant amount of articles that fit the research criteria. Thus, only the main references found in the literature, model adaptations by companies and relationships with new management technologies and products were analyzed.

Finally, the description of the results was focused and critical, structured, as far as possible, to expand knowledge about the topic, given its relevance and relevance in the agricultural machinery sector. There is no profusion of scientific literature in Portuguese on new approaches relating administrative theories and emerging themes; it is suggested to carry out future studies that deepen this field of knowledge in order to identify ways of contributing to new concepts focusing on the application to managers.

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